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# Electronic Business

FOR MANAGEMENT IN ELECTRONICS, COMPUTER & SYSTEMS COMPANIES — WORLDWIDE

AUGUST 21, 1989

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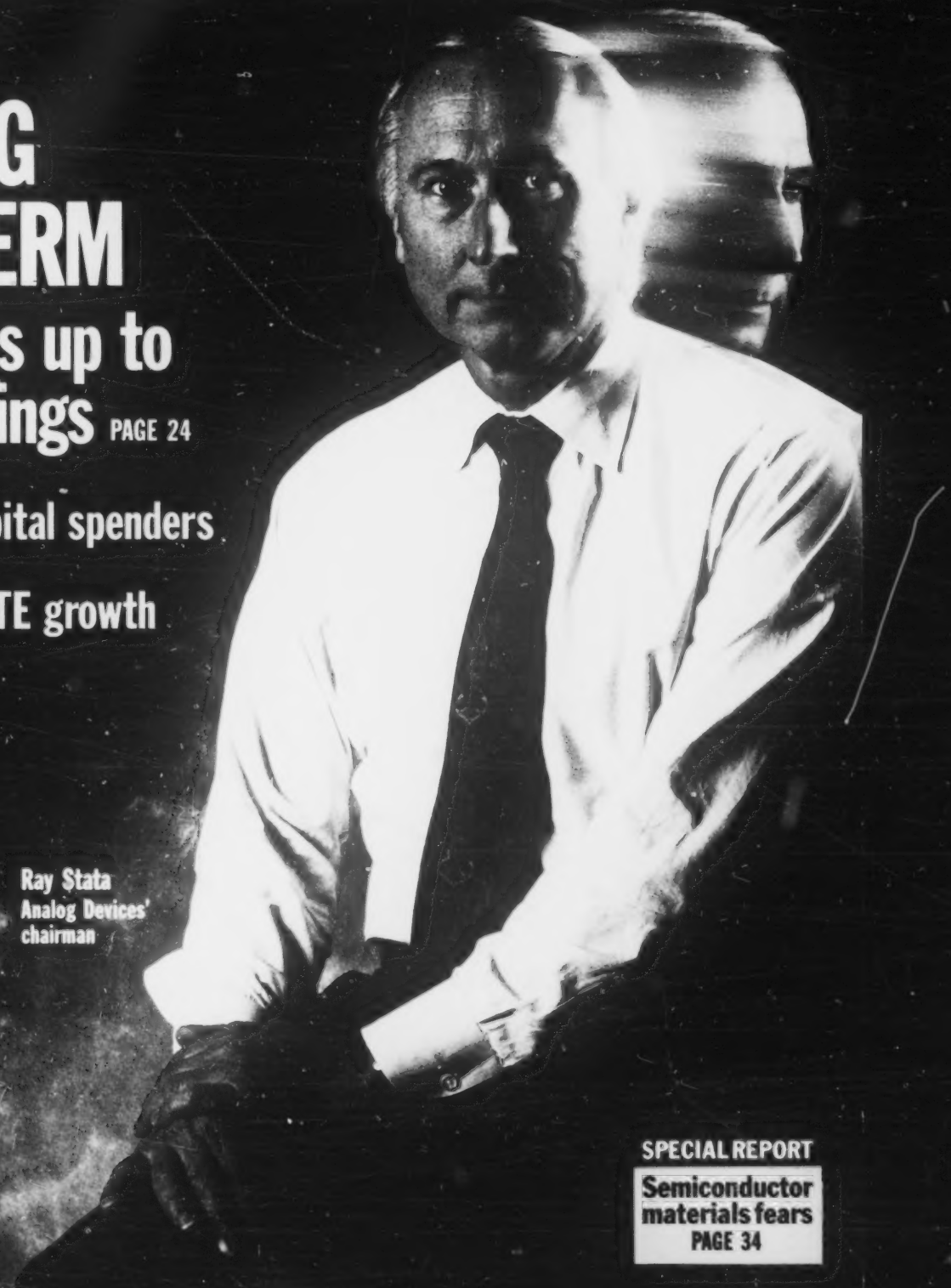

Ray Stata
Analog Devices' chairman

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# Electronic Business

FOR MANAGEMENT IN ELECTRONICS, COMPUTER AND SYSTEMS COMPANIES—WORLDWIDE

VOL. 15, NO. 17 AUGUST 21, 1989

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With the paring down of U.S. military programs, suppliers have been wise to seek new businesses for growth. At chip maker Analog Devices, chairman Ray Stata is staking some of his company's future on supplying ASICs to high-volume markets, such as computers and consumer electronics. But a move into uncharted territory can be sticky, so Stata is taking a methodical approach, not unlike the way a Japanese company would do it. Two first steps: upgrade manufacturing processes and learn to work more closely with customers.

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By fiscal 1992, Analog Devices, the biggest analog IC supplier to the U.S. military, expects to generate just 10% of its overall sales from ASICs. And profits won't come right away either, the company says, because to stay ahead of the technology much of that money will be plowed back into development. But Analog Devices is willing to be patient. In switching the strategic focus to ASICs, "There's a big, big learning curve," says chairman Ray Stata.

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The United States has a startling overdependence on foreign sources for not only its IC production gear but also its raw polysilicon. Already, almost all of the silicon wafers used by the merchant U.S. semiconductor industry come from Japanese- and European-owned sources. While there's no shortage today, the loss of control over materials-supply lines may mean that the United States may not always be able to get wafers when it needs them. In a special report, ELECTRONIC BUSINESS explores the potential impact of a lack of silicon self-sufficiency and offers recommendations for action.


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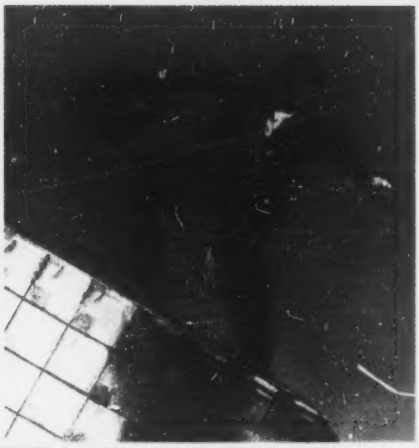

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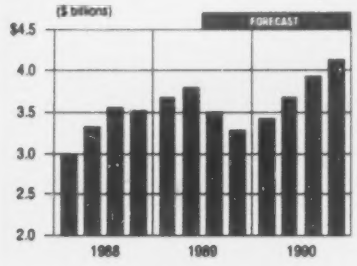


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# Looking long term

When Ronald Reagan took over the U.S. presidency in 1981, the signal to defense contractors was clear: military spending on the whole would increase. But as the cliché goes, nothing lasts forever. And as the "Star Wars" president's first term evolved into his second, another message became increasingly clear: Congress, coming to grips with the ever-rising budget deficit, would begin to pare down defense programs.

For electronics suppliers to the U.S. military, such a slowdown in the growth of the market was cause enough to seek new business areas. Of course, you don't abandon your bread-and-butter markets just because growth has slowed. But, with a look toward the long term, some defense contractors are going after nontraditional niches for growth. Such is the strategy of Analog Devices Inc., the biggest supplier of analog ICs to the military.

Contributing editor Sarah Glazer writes our cover story, illustrating how Analog Devices is seeking new business growth from the unlikely areas of consumer electronics, computers and the automotive industry. Sarah is a longtime follower of electronics, having worked previously as a senior editor for *High Technology* magazine. She is a regular ELECTRONIC BUSINESS contributor and writes our Upstarts column.

At the heart of Analog Devices' strategic shift, Sarah writes, is a plan to supply ASICs to these hot, high-volume markets. Ray Stata, the company's cofounder and chairman, acknowledges that making such a transformation to ASICs is a tall order. Stata is going about his task in a methodical way — a continual chipping away until progress is made. And he readily acknowledges that such an approach is not unlike the way efficient Japanese companies do it. Sarah writes that a near-term goal of Analog Devices is to generate 10% of overall sales from ASICs by 1992.

**Sarah Glazer, contributing editor**

## Silicon self-sufficiency

There's a startling over-dependence among U.S. chip makers on foreign sources for raw silicon. What is more, the chip makers don't seem to care, the U.S. government is indifferent and electronics trade groups are keeping quiet. The U.S. needs a new plan to become silicon self-sufficient, says editor-at-large John Kerr, in his special report in this issue. John argues that a fresh examination of the issue is warranted. He reports that there is cause for concern by the semiconductor industry and offers our recommendations for action.

MARVIN GREENE, section editor

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SPECIAL REPORT

# Silicon self-sufficiency:

## Why the U.S. needs a new plan

BY JOHN KERR

*The U.S. has a startling overdependence on foreign sources not only for its IC production gear, but also for its raw silicon. The Japanese would not tolerate this situation — nor should U.S. chip makers*

The apathy is astounding. If U.S. chip makers — they who care desperately about where U.S. computer firms buy DRAMs — care where their raw silicon comes from, they hide their concern well.

Indifference, it seems, loves company. Washington, the Defense Department included, is dead to the issue. The trade associations keep mum. No Sematech for this one, folks.

Such nonchalance may be a mistake.

Already, almost all of the silicon wafers used by the merchant U.S. semiconductor industry come from Japanese- and European-owned sources. More and more of the polysilicon — the silvery crystalline chunks that are the wafer makers' raw material — comes from Japan. And solid profits in poly and wafer businesses are as elusive as ever.

Texas Instruments Inc. is the latest U.S. chip maker to quit making its own "poly." Monsanto Co.'s sale this past April of its loss-ridden wafer operation to Huels AG of Germany was the most sensational retreat yet, slashing U.S. share of world wafer markets from 21% in 1988 to 3%. And Cincinnati Milacron Corp.'s wafer plant sell-off to Osaka Titanium Co. Ltd. is simply the latest example.

There's no crisis yet. Almost all the merchant wafers used by U.S. chip makers come from U.S. plants, albeit mostly foreign-owned. But should the U.S. continue to make apathy a virtue, control of the materials-supply lines crucial to its merchant IC production base may be out of its hands a decade from now.

Price, availability and technology are the soft parts. Unlike 1989, when American chip makers can all but name their price, 1999 could put them on the pointy end of a sellers' market. While there's no shortage today, the United States may not always be able to get wafers when it needs them. And sorriest of all, it may, as it pushes submicron feature sizes, have to be grateful to get wafers that are less than state of the art.

A problem? You bet. Even though such major players as AT&T, IBM and TI retain solid research and wafer-production activities in-house, there's concern for the industry as a whole — particularly as it relates to tomorrow's technology edge. "The question is whether we can count on getting the latest and greatest [wafer technology]," remarks Robert Noyce, Intel Corp. vice chairman and currently CEO of Sematech, the government-backed United States chip makers' consortium. Warns one United States Commerce Department analyst: "I don't know how an IC device industry can think of being viable in future if it doesn't know who'll be supplying its silicon."

Shades of the oil crisis and the DRAM debacle all over again? Could be.

The problem is neither new nor isolated. It's not a problem of lost jobs; it's mainly about technology transfer, and it is as politically charged as it is technically complex. In fact, the problem of silicon sourcing is only a fraction of the issue at large — the issue of America's self-sufficiency in semiconductors.

It's a problem that forces fresh examination of government's attitude toward technology and one that highlights weaknesses in the relationship between the average chip maker and the average silicon supplier. It transcends the value of the myriad alliances between U.S. and non-U.S. companies. It also illuminates the flaws in a federal tax structure that scarcely encourages long-term investment.

U.S. IC makers already are heavily reliant on Japan for production gear; process chemicals; the masks used to help print the circuit designs; and much else. But silicon's centrality to all phases of IC fabrication and its evergreen influence on everything from manufacturing costs to circuit density make it a pivotal discussion point — and the heart of an issue worth fighting for.

What follows is an attempt at consciousness-raising, an appeal for integrated thinking to acknowledge the dangers in taking too much technological candy from strangers. In this special report, ELECTRONIC BUSINESS explores the potential impact of a lack of silicon self-sufficiency and offers recommendations for action. The actions, we believe, the industry should take before it's too late. □

Karin Hawkins

SPECIAL REPORT

# Defining the problem

Ah, the cute little microchip! How clever and quick you are! How famous and proud you've become! So proud, in fact, that you seem to have forgotten the quaint materials that made you possible in the first place.

Don't. They still control your future.

"The lack of R&D and lack of participation [in silicon materials by U.S. companies] may exclude the U.S. from new business that will depend on silicon in ways we can't put a finger on right now," warns William O'Mara, a vice president with Los Altos, California-based electronic-materials consultancy Rose Associates.

Meaning: Japan in particular is edging ahead in the basic materials science that could yield entirely new generations of ICs.

Its nondefense R&D spending accounts for 2.8% of GNP, compared with the U.S. level of 1.8%. While specific figures on materials research are not easily available, anecdotal evidence of Japan's edge abounds.

Also, Japan's chip makers are, by all accounts, tighter with their silicon suppliers than their U.S. rivals — with real payoffs. Sources maintain that Toshiba Corp. owes its high yields and strong productivity in one-megabit DRAMs to its direct funding of its wafer-making Toshiba Ceramics subsidiary, and to an intimate sharing of IC performance and process goals with poly suppliers such as Komatsu Electronics Inc.

Consider the following hypothetical scenario:

The world's largest silicon wafer maker, a Japanese firm, decides it wants more control of the world's polysilicon supply and boosts to a controlling interest its current 24.5% stake in the major United States poly supplier. The poly firm's parent, currently a majority shareholder with 63.25%, is only too happy to oblige to appease stockholders concerned with the poly unit's meager profits.

The Japanese player, suddenly with more than 15% of world polysilicon capacity, feels it has the economies of scale and the deep pockets to pull pricing initiatives. It begins offering poly at $35 per kilogram — the norm is over $40 today — and a year later, its market share gain is noticeable.

A giant U.S. chemicals conglomerate, still struggling to have the poly from its new $100 million-plus plant qualified with more customers, feels the heat as shareholders lose patience. Already in litigation with Japanese rivals over alleged dumping, it ups the tempo in the courts — loses in them — and mothballs the facility.

Japan's share of world capacity — to cut world overcapacity, no Japanese company buys the silent U.S. plant — rockets from the current 30% (treble its share in 1979) to 60%, with its chief rival —a West German company — grimly hanging on to most of the rest.

Building on its manufacturing and R&D strengths, and on its stronger control over raw poly, the Japanese player begins offering U.S. customers cleaner, flatter wafers, using this as a lever to pump prices much as Japanese automakers blunted trade quotas by adding value. The across-the-board increases push some marginal U.S. chip makers over the edge; other larger IC firms, unable to pass along the added cost to computer customers, lose share.

Our Tokyo-based dynamo is now making enough profit overseas to be able to relax prices domestically, enhancing the competitiveness of Japanese chip makers. Those customers also win the first allocations of wafers, forcing U.S. customers to the back of the queue and into leadtimes of eight months.

**Japan's payoff**

Years pass. Japanese silicon suppliers begin to earn the payoff from a decade of intensive R&D spending on surface contamination and defect analysis. Their wafers produce economies of scale — 8-inch and larger wafers that are flat and clean enough to produce high yields in mass production — and the flawlessness necessary to get down to 0.2-micron linewidths with ease. Favored Japanese chip makers get samples six months ahead of U.S. and European customers, and are first to market with the one-inch square half-gigahertz microprocessors and the microscopic 256-megabit DRAMs that the gigantic pocket-computer industry of the late 1990s is waiting for.

End of story. Sounds alarming to U.S. ears? Certainly. Is it plausible? In essence, yes.

There are many worrisome precedents. Foreign auto makers' inroads are a classic example; for instances closer to home, look at Japan's rise to dominance in IC packaging materials, and the infamous DRAM skirmishes. (Comparisons with the DRAM problem require care: although tight interrelationships exist, the silicon business does not enjoy the same degree of vertical integration that Japan's chip-through-computer sectors do. Also, the foreign silicon firms maintain considerable United States manufacturing operations.)

This is not to say it will happen — only that it *could* happen. There's plenty to conspire against it: U.S. government trade blocks; combined action

**Problems: A - Z**

**The U.S. silicon supply base is in trouble because:**

- There's no widespread awareness, acknowledgement or understanding of the problem
- There's less commitment to long-term materials research than elsewhere
- There's a harmful urge toward "commodity buying" of wafers
- U.S. wafer suppliers are lucky to make 3% net income in good times and usually lose over 5% on sales in bad times
- U.S. cost of capital is high and capital investment focus is too short

by U.S. chip makers, broader global technology liaisons; the rise of a new U.S. technology; emergence of different chip-production techniques. Some, such as Intel Corp.'s manager of fab materials, Fred Voltmer, see safety in continued imports: "As long as foreign silicon firms export to the U.S., we'll get the technology."

Others like to know that many of the foreign-owned wafers they buy come from the U.S. factories of Japanese world wafer leader Shin-Etsu Handotai Co. Ltd., West Germany's Huels AG and others. "That makes me feel a little better," says Stephen Cooper, president of Beaverton, Ore., IC maker Bipolar Integrated Technology Inc.

### Cold comfort

There's comfort for many in knowing that IC technology leaders such as IBM and AT&T keep wafer production in-house. Altogether, notes Rose Associates, U.S. captive wafer production, at around 70 million square inches a year now, comprises about 15% of total U.S. needs.

And there's a train of thought among U.S. chip makers that says it doesn't matter who makes the wafer substrates because of the growing popularity in the merchant market of "epi" — the epitaxial wafers whose bare substrates are coated with a vapor-deposited layer of pure silicon. Epi can be brought in-house for a capital cost of about $1.8 million; including operating costs, an IC maker — provided it has the output to justify the investment — can control its own wafer surface make-up for under $800,000 yearly.

**"From a half-micron linewidth and beyond, silicon material purity is becoming critical"**

**A senior IBM technologist**

### Complacent

But others with a mandate to look further than next month's supply show more unease. Says Hector Ruiz, director of technology for Motorola Inc.'s semiconductor operations: "I believe we [as a nation] are being a little complacent about silicon. The level of concern should be heightened." Adds another industry executive: "I think it's scary."

The components of the problem are several, and perhaps the most immediate is that voiced by Ruiz: there's no real base of concern, and little understanding of the problem.

As a natural consequence, it's no surprise that materials research is not on the IC industry's front burner. Nor is it astonishing that IC makers hurt their wafer suppliers more than they help them by nickel-and-diming them to death. Chip makers' buyers, motivated to get the best possible price, insist that quality is purchase parameter No. 1, but continue to treat wafers as commodities. "IC makers are doing the same thing with their suppliers that they've accused their customers of doing," argues a senior Commerce Department analyst.

### Pitiful profitability

The pricing issue is key to another aspect of the problem: the pitiful profitability of wafer makers. By one senior Intel executive's estimate, wafer suppliers are hard-pressed to make 3% to 4% net income on sales

## Why no one seems to worry

U.S. politicians have this giddy belief that because silicon is made from the same stuff as sand, Saudi Arabia ought to have a lock on the chip business.

Just goes to show: you can take a pol to wafer, but you can't make him think.

Political naiveté about the intricacies of the issue is only one reason why no one is up in arms about silicon self-sufficiency. Nor is it perceived to be a "national security" hazard — meaning that the Defense Department can still locally source the semiconductors it needs for its most advanced technology.

Hence a government that only smiled politely when Samuel Harrell, president of Semi/Sematech, a group of United States equipment and materials vendors formed to work with Sematech, took issue with the federal interagency group whose conclusions led President George Bush to permit the Monsanto sale earlier this year.

Washington now understands something as feted as the chip; that, spiced with some particularly vociferous lobbying, quickly gave America's DRAM deficit star billing. More moaning to Washington made the pols understand that something had to be done about U.S. chip-making prowess — hence Sematech.

And the lawmakers' ready appreciation for the power of the "tube," plus the American Electronics Association's shrill campaign, mean enthusiasm galore for high-definition TV.

But there's no such furor over America's silicon overhang. It's easy to see why:

- First, materials are to ICs what sawmill rough cuts are to Chippendale chairs: decidedly unlovely.
- Second: If you think your congressman has trouble figuring out what software is, imagine how he or she will cope with superlattice structures.
- Third: The IC production process is today's principal bottleneck, not the materials technology.
- Fourth: Most U.S. chip makers, getting adequate quantities of high-quality wafers on time and at good prices, are happily and legitimately wed to foreign suppliers (at least for their own offshore plants' needs) and have no intentions of rocking any boats.
- Fifth: The considered view is that the real value-added in an IC is in the circuitry. Uncoated substrates — polished wafers — account for only about 5% of the manufacturing cost of a typical IC device.
- There is a sixth reason for silence over silicon: the federal government has enough on its plate as it tries to prioritize its myriad high-tech trade worries. And Uncle Sam is too committed to the free-trade ethos to worry unduly about strategic sourcing. □

**Hector Ruiz, Motorola's director of technology: Worried by the potential impact of Japan's apparent lead in materials technology**

in good times, and when times are bad, they'll usually drop to 5% net losses. "You've got to have more upside than downside," he says. There's no history of that.

St. Louis-headquartered Monsanto Co.'s case is not unusual. From 1983 until the sale this April to Huels, its wafer-making unit lost an aggregate of about $270 million on sales that in any one year never topped $185 million. Monsanto declares a corporate goal of 20% return on equity.

But Japan's wafer makers, headed by world market share leader Shin-Etsu which had estimated 1988 sales of over $450 million, are, according to Rose Associates, riding to profit on the back of the higher-margin six-inch wafers that were demanded by last year's DRAM boom. Next stop: wafers for the imminent wave in 4Mb DRAMs.

Explains a recent issue of Rose Associates' *Electronic Materials Report*: "150mm wafers for 4Mb DRAMs are viewed as the growth and profitability segment of the industry. Those that can optimize their yields to these stringent specifications at an early date will be able to drop profits to the bottom line. But the window of opportunity here will close rapidly as many of Japan's 10 wafer makers get quickly up the learning curve, and competitive pricing once again begins to erode profits."

The story's no different for U.S. makers of the polysilicon. They face a world market where the production plants currently can churn out 60% more of the silver-gray stuff than anyone needs.

Compounding the financial problem is America's low tolerance for poor short-term returns, and its exorbitant cost of capital. A recent white paper from the American Electronics Association entitled: "America's Future At Stake: Winning in the Global Marketplace," claims that a U.S. company acting rationally can forsake $1 of current earnings for $1.20 in future earnings only if the payoff comes in less than three years — a quarter of the time span that its Japanese equivalent can endure.

Says Sematech CEO Robert Noyce: "I see [the weakening of the U.S.-owned silicon supply base] as a symptom of a fundamental sickness; America is not savings-driven enough. The main issue is that America, because of its shortage of investment capital, is going to have continuing problems like this."

You said it, Bob. □

## Is it the same story in GaAs?

By 1991, the joke goes, suppliers of gallium-arsenide (GaAs) IC wafers will be offering their products for free. A year later, they'll be shipping a $100 bill in every box of wafers.

The joke refers to the steep slide in the price of the three-inch wafers that make up the mainstream production of such GaAs chip makers as GigaBit Logic Inc. and Triquint Semiconductor Inc. Costing about $900 in 1982, the wafers are now tagged at around $165 and under $150 in large volume.

With yields on GaAs semi-insulating wafers climbing rapidly and substantial overcapacity in place, that price can be expected to keep sliding sharply. As with the silicon business, wafer makers reap little or no profit, and deep-dive prices won't help.

An inescapable consequence is attrition among wafer suppliers; sources that track the GaAs supply predict that only about 18 firms will be active by 1994, compared with about 25 today. That, of course, will be welcome to the survivors: Says Dr. Russell Kremer, staff scientist at Colorado Springs-based GaAs wafer firm Crystal Specialties International, a foreign-owned firm which intends to be among that number: "About the only way you can make money is to increase market share."

That, coupled with a growing obsession with repeatable quality, favors the players with the deep pockets — like top-ranked Sumitomo, which has about 15% of the world's GaAs wafer markets. The jury is still out — observers say it's still up for grabs which country dominates the GaAs materials market. In 1988, the U.S. has 47% of semi-insulating GaAs wafer production against Japan's 32% and Europe's 20% of a $21 million market worldwide; the United States, consuming 60% of world output, is a net importer.

But there are telling pointers of future market dynamics. Says Crystal Specialties' Kremer: "Some very nice work is being done by Japan in GaAs in consumer electronics." □

SPECIAL REPORT

# Waiting out a poly plethora

To say that polysilicon is a buyers' market is to point out that the Pope is Catholic. Worldwide, there is about 60% more poly production capacity than consumption.

It could be worse. According to one market researcher, the PC madness of the mid-'80s produced dollar-crazed plans for 23,000 metric tons (tonnes) of poly capacity by 1990 — over twice current potential.

Today, global poly capacity is put at around 10,800 tonnes yearly — under 5% of it for photovoltaic uses — by consultancy Rose Associates, with usage at about 6,800 tonnes. Poly makers don't see signs of the two balancing out before 1995.

The overcapacity issue is one that hurts U.S. suppliers and favors those with the longer view and deeper commitment. Significantly, Japan's portion of worldwide capacity has ballooned: from just over 10% a decade ago to nearly 30% today, with Rose Associates projections figuring almost 40% by 1991, assuming that all the players stay in the game and under their present owners.

The folks who invest in poly plants are made of the same stuff as Peace Corps volunteers. You'd need to be optimistic, and deep-pocketed too, to live with no return for year after year, and with no relief in sight.

With overcapacity as it is, there's little prospect of availability or pricing problems for poly customers well into the 1990s. James McCormick, president of major U.S. producer Hemlock Semiconductor Corp. in Hemlock, Mich., has adapted the Boston Consulting Group experience curve to plot accumulated tonnage against price per kg., and it's a steady slide to the right.

Wafer makers know it — and as beaten over the heads on price as they are, they expect it. Consequently, price per kg. has eroded from $70 to $80 15 years ago to just over half that now. Prices of $42 in small quantities are not uncommon.

Compounding the issue is the higher utilization of wafers — higher yields than ever mean slower demand growth.

It's tough for poly makers. Some, like Japanese steel giant NKK Corp., bought older U.S. plants and laid out grand plans for new plants on U.S. soil before shelving everything. Texas Instruments Inc. and Motorola Inc. recently shut down their own poly operations. And Union Carbide Corp., although it set a 1,200-tonne facility going a few years back, is locked in lawsuits charging that seven Japanese suppliers created a price-cutting cartel.

Although the poly processors play their financials very close to the vest, few observers believe that they're profitable. With little hope of reasonable price increases until overcapacity is mopped up, the only escape route is through beating down process costs. And there are limits to that: because poly is made by building up crystal deposits on an electrode, its production has a ferocious appetite for electricity.

Present production costs per kilogram of poly run about $20; depending on speed of deposition, local electricity costs and a few other factors some poly makers could see electrical power accounting for well over two-thirds of their process costs.

"Everybody hopes for better times. Staying below the [price-cumulative volume] curve is really our driving force," sighs Hemlock's McCormick.

### High hopes

One newer U.S. player — Richmond, Virginia-headquartered chemicals giant Ethyl Corp. — has hopes of staying way below the curve, aiming for a return on investment of over 15%. Relying on a new process that produces polysilicon pellets with more efficiency than the conventional techniques, Ethyl has, in six years, moved from pilot plant to full-blown 1,250-tonne-per-year facility — an investment of just under $45 million whose capacity can be doubled for an extra $20 million.

Things aren't going quite as smoothly as Ethyl had hoped, though: "Our market penetration has been slower than we would have liked, primarily because of long qualification times and market overcapacity," says Fred Anderson, marketing manager for silicon materials at Ethyl's electronic materials division. He also cites a practice he claims has been gaining ground in the past two years: the ability of IC makers to veto their wafer suppliers' poly sources.

The old Monsanto wafer facility — now owned by German giant Huels — is Ethyl's only volume customer; others are sampling and qualifying. Consequently, the Louisiana plant is

## More polysilicon than anyone wants

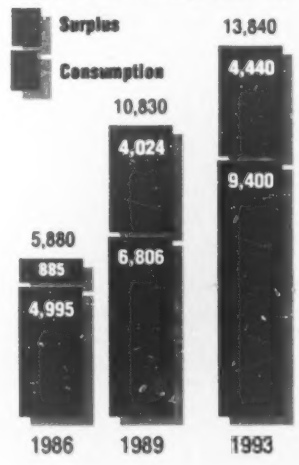
### Shifting capacity shares

Polysilicon capacity (metric tons)

| | 1984 | 1988 |
|---|---|---|
| **U.S.** | | |
| Hemlock | 1,300 | 1,500 |
| Union Carbide | 100 | 1,200 |
| Ethyl | 0 | 1,250 |
| Texas Instruments | 250 | 0 |
| Monsanto | 230 | 0 |
| Motorola | 50 | 0 |
| Great Western | 200 | 0 |
| Total U.S. | **2,130** | **3,950** |
| **Japan** | | |
| Tokuyama Soda | 200 | 1,200 |
| High Purity | 800 | 1,100 |
| Osaka Titanium | 360 | 600 |
| Shin-Etsu Handotai | 150 | 150 |
| Komatsu | 70 | 70 |
| Total Japan | **1,580** | **3,120** |
| **Europe** | | |
| Wacker | 2,400 | 3,000 |
| Huels (DNS) | 350 | 400 |
| Total Europe | **2,750** | **3,400** |
| **Total world** | **6,460** | **10,470** |

### Consumption vs. capacity

Worldwide merchant and captive polysilicon capacity (metric tons)




Source: Rose Associates

running at half-capacity, with Anderson's aim being two-thirds capacity by year-end.

The lessons from the poly business are several. First, today's overcapacity won't last forever, and could quite quickly turn to shortage unless the poly crowd has the full forecasting cooperation of its customers, and its customers' customers.

How? Because IC demand, higher utilizations aside, climbs relentlessly, and because it takes about two years to build and bring a new poly plant on stream. Don't expect the producers of the pewter-colored chunks to say "How high?" when chip makers tell them to jump next time; the mid-1980s mania has cured them of that.

Second: this is a high fixed-cost business: Ethyl's $45 million outlay seems to be the minimum, and plants of around 1,000 tonnes capacity are about the optimum. The people with best access to low-cost capital live in — you guessed it — Japan. □

# Wafer firms feel the squeeze

U.S. chip makers don't know their own purchasing strength. "They've got enough clout to squeeze their wafer suppliers," says Richard Winegarner, CEO of Sage Concepts Inc., a research firm that tracks silicon supply dynamics.

And squeeze they do. "We're asking them to do more for less," says Paul Luvisi, Hewlett-Packard Co.'s corporate procurement manager for chemicals and materials, of his wafer suppliers.

Confirms Michael Christ, president of one small U.S. wafer maker, Recticon Corp.: "We've seen customers decide on the basis of a few cents' difference."

IC makers, of course, would have you believe that they buy primarily on quality. While clearly true, this does not excuse their fixation with price when it may come at the expense of their supplier base. "The IC purchasing guy is successful on a micro scale, but on a macro scale, he's killing the [U.S. wafer] industry," explains Sage Concepts' Winegarner.

Although supply and demand worldwide are roughly in balance — worldwide wafer consumption (merchant plus captive) this year is 1,621 million square inches, according to Rose Associates — there's little letup in prices.

Today, the 4-inch polished wafers that are the mainstream are priced at under $10 in volume, with epi wafers about treble that. Six-inch polished wafers cost over $20. U.S. IC makers appear to be expecting a 15% to 20% drop in polished-wafer prices over the next two years, and for at least the same in epi.

The complaints from the wafer side are predictable. "This industry is still underpriced in regard to its cost of manufacturing," says Recticon's Christ.

About the only time it wasn't so was in the year that PCs were everybody's darling: 1984. Prices rocketed as leadtimes stretched from today's comfortable eight weeks for polished substrates to 42 weeks.

Today, the only complaints of availability surround epi, where delivery is taking up to 25 weeks, in the case of one customer.

Can 1984 happen again? It's unlikely. Price and availability of silicon wafers will remain fairly stable for the foreseeable future, especially with Europe acting as the counterbalance to Japan's wafer weight.

### German challengers

West Germany's two silicon titans — Huels and Wacker Chemis GmbH — are formidable challengers. Now that Huels owns Monsanto's facilities, the Teutonic pair has cornered nearly 35% of the world wafer market this year against Japan's 62%. Huels, a relative newcomer to the business, now goes head-to-head with Shin-Etsu for market leadership.

Huels, Wacker, Shin-Etsu and many of the other foreign players have production in the United States; as part of its purchase, Huels has committed not only to expand American production but to maintain a strong R&D effort in the States. "We're a stronger company than under Monsanto," vows Roger McDaniel, CEO of the new U.S. operation, called MEMC Electronic Materials Inc.

Huels also indicates willingness to support Sematech, a prospect that makes some U.S. observers shudder as they monitor Europe's aggressive efforts in semiconductors. "You can see the technology leakage path there already," warns a top Commerce Department official. □

## How world wafer-making has changed hands

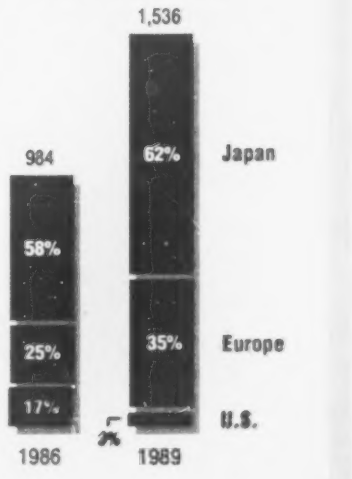
### Players, then and now

Merchant wafer production (millions of square inches)

| | 1986 | 1989 |
|---|---|---|
| **Japan** | | |
| Shin-Etsu Handotai | 270 | 345 |
| Jasil/Siltec | 96 | 190 |
| Osaka Titanium | 100 | 160 |
| Komatsu | 58 | 115 |
| Others | 50 | 135 |
| Total Japan | **574** | **945** |
| **Europe** | | |
| Wacker | 195 | 220 |
| Huels (DNS) | 46 | 310 |
| Others | 6 | 10 |
| Total Europe | **247** | **540** |
| **U.S.** | | |
| Monsanto | 125 | — |
| Cincinnati Milacron | 8 | — |
| Others | 30 | 51 |
| Total U.S. | **163** | **51** |
| **Total world** | **984** | **1,536** |

### Merchant market shares

Merchant wafer production (millions of square inches)




Source: Rose Associates

SPECIAL REPORT

# May the cleanest wafer win

The elder statesmen of the IC business remember well: the days and nights spent tinkering with weird materials to cook up just the right semiconducting properties. "This industry was driven by materials from the start," says Fred Voltmer, Intel Corp.'s manager of fab materials.

Not so now; the emphasis, as any EE college kid will tell you, is on design. But that may soon have to change.

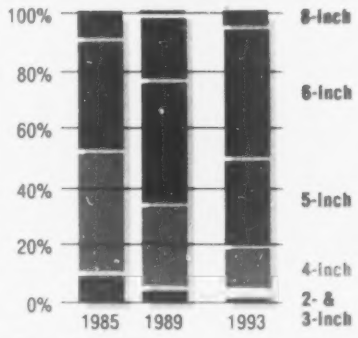
Present-day chips and their production economics are constrained chiefly by process, not by raw material chemistry. But the newer devices are starting to impose tougher demands, right down to the poly level. "We do know that polysilicon does influence the performance of our devices. Defects in the bulk material have to be more and more controlled," according to Intel's Voltmer.

There are plenty who say that Japan is well ahead of those demands. Says a senior staffer at a prominent electronic-materials laboratory: "The irony is that the Japanese take out impurities *before* it's important because they expect it will become important. I think that some differences [in bulk materials chemistry] will show up in the next five years that will screen out some silicon versus other silicon."

In other words, a new, purer standard is coming. Those that anticipate and meet it get the business.

## Big wafers are coming and they have to be clean

Worldwide wafer mix (Percentage of square inches of wafer surface, merchant and captive)




Source: Dataquest Inc.

United States poly suppliers such as Hemlock Semiconductor Corp. — a joint venture between Dow Corning Corp., Japan's Shin-Etsu and a unit of Mitsubishi Metal Corp. — and chemicals giant Ethyl Corp. are proud of the immaculacy of their materials. "We reached semiconductor-grade very quickly," boasts Fred Anderson, marketing manager for silicon materials at Ethyl's electronic materials division. He boasts of phosphorus content down to one-tenth of a part per billion (atomic), and only two-tenths parts per million for carbon. Heavy-metal (chromium, iron, etc.) levels —another critical determinant of performance —have been whittled from 15 ppb to 5 ppb in the last few years, with promise of dropping lower still.

Not good enough, say those in the forefront of IC technology. As manufacturers bring up volume processes for making devices with tighter and tighter linewidths, purity (repeatable purity) must push down into the parts per trillion — the limits of the equipment being used today to measure that purity. "From a half-micron [linewidth] and beyond, it's becoming critical," says a senior IBM technologist.

Critical at least for satisfactory manufacturing yield; when it comes to the performance of the device itself, parts-per-trillion cleanliness may be demanded for the 0.1- or 0.2-micron linewidths that may be in volume production 15 years ahead.

Why precisely will it matter? Because unwanted impurities such as carbon and oxygen and heavy metals, and point defects such as vacancies in the atomic lattice, lead to fundamental performance flaws such as electrical charge leakage and reduced lifetime. They also foul up some IC manufacturing steps such as diffusion and ion implantation.

### Sagging wafers

Another killer: impurities and defects govern the mechanical strength of the wafer. That matters with the larger 8-inch wafers that will appear

## Nuclei for revival?

All is not lost. Here are a few building blocks for a revival of U.S.-owned capability in silicon:

- Under wraps: A voluntary initiative by an independent U.S. group believed to be exploring the mutual goal of less reliance on foreign-owned silicon sources. Believed to comprise at least one U.S. chip maker; a U.S. polysilicon supplier; and a U.S. wafer maker.
- Wafer production is still in place at IC units of, among others: Texas Instruments Inc.; IBM; AT&T; and Motorola Inc.
- The existence of the National Advisory Committee on Semiconductors, a top-level body formed under Omnibus Trade and Competitiveness Act to report to Congress to help formulate national policy.

It includes such industry luminaries as TI chief Jerry Junkins, Applied Materials Inc.'s Jim Morgan, National Semiconductor Corp.'s Charlie Sporck; and has a technology subcommittee. It is expected to finalize recommendations next month.

- The Sematech effort to modify U.S. legislation under the Trade Act to determine and accommodate the strategic nature of materials sourcing.
- Expertise in materials in laboratories such as: Bell Labs; David Sarnoff Research Center; University of Illinois; UCLA; Stanford; MIT; and in materials analysis at analytical labs like Charles Evans & Associates;
- Expertise in materials in IC firms such as: Texas Instruments; Motorola; AT&T; Intel; IBM;
- Expertise in silicon-making infrastructure: crystal-pulling machinery from firms like Kayex (a General Signal Corp. unit); wafer polishing pads from firms such as Rodel Products Corp.
- Sematech's effort in materials research.

in volume in the mid-1990s: they're big enough and thin enough to sag under their own weight, which wreaks havoc with the focus when trying to imprint pin-sharp circuit patterns all over the wafer's surface.

The machining of wafers from ingot is equally critical: wafer flatness and surface roughness take on new importance as circuit densities increase and 6- and 8-inch wafers come on stream. The micro-roughness to some extent governs the quality of epitaxial layers grown on the substrates: the flatness governs the sharpness of the circuit images repeatedly printed across a wafer.

Other phenomena are barely understood, but may prove critical in the next decade. Recent Japanese research indicates that no matter how clean you get a wafer, it will still "remember," through a puzzling chemical characteristic, its original condition and revert to that.

Familiarity with surface chemistry will become mandatory too: as IC device sizes shrink, surface-to-volume ratios change, forcing IC performance and manufacturing cost-efficiency to rely more on surface makeup.

**"IC makers are doing the same thing with their suppliers that they've accused their customers of doing"**

**Senior U.S. Commerce Department analyst**

That wafer cleanliness is more important than ever is reflected in the U.S. start-ups that have obtained funding to develop cleaning equipment for use in wafer fabs. Examples include: CFM Technologies Inc. of Lionville, Pa., and Advantage Production Technology Inc. of Sunnyvale, Calif.

U.S. start-up activity aside, consensus points to Japan's occupation of the R&D high ground. Says Intel's Fred Voltmer: "The Japanese are spending a tremendous amount on surface chemistry [at a rate that] is not being replicated in the U.S." Japan is also pushing the frontiers of metrology, on the premise that if you can't measure a flaw, you can't make it go away.

That's a position which, as more and more control of the basic silicon markets heads east, can only be strengthened. Laments one U.S. silicon scientist: "We just don't have the inner drive to make things cleaner and reduce variability, and the Japanese do. U.S. firms just don't want to know." □

## Action items: Where to from here?

Accepting that U.S. chip makers are over-reliant on foreign sources for their silicon, what should be done? Here are a few guidelines:

| Who should act | What they should do |
|---|---|
| Sematech board members | Bolster Sematech's basic materials research — particularly bulk silicon purity and consistency, wafer surface contamination, defects, measurement methods and wafer-cleaning techniques. |
| IC, wafer and polysilicon executives | Promote much closer working relationships — employee exchanges, sharing of more IC design data — between chip makers and their silicon suppliers. |
| All IC- and related-industry executives | Champion formation of multi-industry consortium or joint venture to research advanced silicon materials and processes. Venture to include molten-materials processors, (steel or chemical companies), crystal pullers (silicon wafer makers), IC makers, IC equipment and chemicals makers and selected IC users. |
| All IC- and related-industry executives | Champion formation of a similar venture to produce advanced materials, preferably without government funding. Joint DRAM venture — U.S. Memories — is a prospective model. |
| IC executives | IC makers should consider buying equity in wafer, poly suppliers. |
| IC CEOs, CFOs | Explore mechanisms for floating intra-industry low-interest funding to support future silicon production. |
| AEA, SIA, EIA, CBEMA | Back proposed legislation to increase funding for a silicon-materials study by the National Institute for Standards and Technology. |
| Procurement managers at IC makers | Foster organizational mechanisms for reducing "commodity buy" tendencies in IC firms' purchasing departments. Encourage IC makers to ease wafer cost targets; strike longer contracts for higher quality and guaranteed delivery; reward buyers on wafer quality beyond spec. |
| Managers of U.S.-owned IC operations overseas | Foster mechanisms for technology feedback from abroad. Encourage U.S.-owned offshore IC plants to partner more tightly with foreign silicon suppliers. |
| IC wafer-facility managers | Encourage existing IC makers that make wafers to consider supplying merchant markets |
| R&D directors at IC makers | Concentrate more R&D expertise on alternative high-performance IC structures, such as silicon-on-insulator wafers. |

# Capital spending hits four-year high in 1988

*But don't look for more big gains by the ELECTRONIC BUSINESS top 100 capital spenders in 1989. A "be cautious" leveling off is expected*

BY BRUCE C.P. RAYNER and LINDA STALLMANN

Capital spending by the top U.S. electronics companies hit a four-year high in 1988, posting a healthy 28% growth over 1987. But last year's good performance is expected to be the peak of the cycle as market watchers are forecasting a leveling off in capital spending this year and next as a result of fallout from higher interest rates and a slowing economy.

Total capital spending by the top 100 publicly held U.S. electronics companies in an exclusive ELECTRONIC BUSINESS survey rose from $18.3 billion in 1988, up from $14.3 billion in 1987. But while this represents a healthy commitment to expansion, the industry nonetheless remains cautious about expanding capacity too fast after the boom/bust experience of four years ago. In nominal terms, the 1988 figure is still below the peak of $20.8 billion reached in the boom year of 1984.

Topping the ELECTRONIC BUSINESS list of capital spenders last year was none other than IBM, with a total of $5.39 billion, up 25% from 1987. IBM accounts for 29% of the total spending by the top 100 companies. Indeed, most of the industry's capital spending is done by the biggest companies: the top 10 companies on the list spent 68.5% of the total. To qualify for inclusion on the list, a company must be a publicly held U.S. company, derive at least 70% of its sales from electronics and be listed on the ELECTRONIC BUSINESS 200 ranking [ELECTRONIC BUSINESS, July 24, 1989].

But while IBM spent the most, it was DRAM-maker Micron Technology Inc.'s spending that grew fastest. It outstripped all the rest by increasing capital spending a whopping 877.6% to $44.3 million as it capitalized on the DRAM shortage. The company reportedly will boost spending by 376% in 1989, according to semiconductor analyst Jonathan Joseph, Montgomery Securities, in San Francisco.

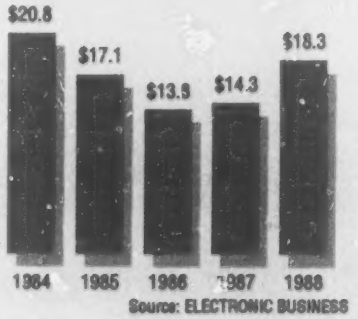
Surprisingly, it was neither the heavy-spending computer sector nor the capital intensive semiconductor sector that captured last year's top growth catagory. Instead, it was the tiny software segment that took first place with an average 1988 growth rate of 79.9%.

In dollar terms, software accounted for only 1.2% of capital spending by the top 100 electronics companies on the ELECTRONIC BUSINESS survey. At the top of the software spenders was Ashton-Tate Corp., up 459% to $36.4 million as a result of acquisitions. The company plans further expansion in Singapore this year.

Behind fast-growing software came peripherals, with a 75.8% growth rate in capital spending in 1988. It was in this category that the wildest swings took place. Seagate Technology, in 13th place last year, rose in the overall capital spending ranks from 30th place in 1987, while 45th-ranked Storage Technology Inc. plunged from 14th place as it recovers from three years in bankruptcy.

**Capital spending levels**

Total capital spending by the top 100 U.S. electronics companies ($ billions)




Source: ELECTRONIC BUSINESS

### Expect stagnation

What's in store for 1989?

Stagnation, says Cahners Economics' Madeline Franchi. "In general, growth in business investment by electronics companies in new plant and equipment reached its peak at the end of 1988, and we are seeing some definite softening in 1989," she says. But economist Franchi anticipates a turnaround in the electronic industry's capital spending plans in 1990 and a "resurgence" in 1991 as the economy recovers from the slowdown of late 1989 and early 1990.

But industry observers say that even though the sluggish economy will slow total capital spending in 1989, electronics companies have no choice but to continue to spend on productivity-improving equipment. That means out of a smaller pie, less will be spent on increasing capacity while more will go to replacement and modernization.

Indeed, Data Resources Inc. is forecasting the percentage of capital spending devoted to expansion to drop from 32% in 1988 to 28% in 1989 for all manufacturing industry. The trend is reflected in the subcategories of electrical machinery, 29% to 21%; nonelectrical machinery, 24% to 16%; and instruments, 34% to 33%.

Compounding this shift is the ever-increasing pressure from foreign competition. For instance, the top 10 Japanese chip makers plan to increase spending by 75% to $4.8 billion this fiscal year, ending next March, while the top 11 U.S. companies will increase spending by only 22% to $3.2 billion in calendar 1989, says analyst Joseph. □

## Top U.S. capital spenders

| Rank 1988 | Rank 1987 | Company | Total capital expenditures ($ millions) | Change from 1987 | Capital expenditures as a percentage of revenue | Capital expenditures to net cash flow after dividends | Fiscal 1988 revenue ($ millions) | Fiscal year ended |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | IBM | $5,390.0 | 25.2% | 9.0% | 70.5% | $59,681.0 | 12/88 |
| 2 | 3 | Digital Equipment | 1,517.6 | 102.8% | 13.2% | 82.8% | 11,475.5 | 6/88 |
| 3 | 2 | Xerox | 1,399.0 | 49.3% | 8.5% | 167.7% | 16,441.0 | 12/88 |
| 4 | 5 | Motorola | 873.0 | 32.7% | 10.6% | 96.5% | 8,250.0 | 12/88 |
| 5 | 4 | Unisys | 669.9 | -7.1% | 6.8% | 60.0% | 9,902.0 | 12/88 |
| 6 | 6 | Hewlett-Packard | 648.0 | 27.8% | 6.6% | 57.9% | 9,831.0 | 10/88 |
| 7 | 8 | Texas Instruments | 628.1 | 35.7% | 10.0% | 93.9% | 6,294.8 | 12/88 |
| 8 | 7 | GM Hughes Electronics | 533.0 | 13.5% | 4.7% | 55.7% | 11,243.6 | 12/88 |
| 9 | 11 | Intel | 477.5 | 58.3% | 16.6% | 71.9% | 2,874.8 | 12/88 |
| 10 | 9 | NCR | 420.4 | 8.0% | 7.0% | 66.1% | 5,989.9 | 12/88 |
| 11 | 10 | Honeywell | 327.7 | 7.7% | 4.6% | -136.0% | 7,148.3 | 12/88 |
| 12 | 12 | Pitney Bowes | 309.5 | 22.9% | 11.7% | 93.5% | 2,649.9 | 12/88 |
| 13 | 30 | Seagate Technology | 284.4 | 262.8% | 22.6% | 221.7% | 1,257.0 | 6/88 |
| 14 | 18 | Amdahl | 278.9 | 76.8% | 15.5% | 88.4% | 1,801.8 | 12/88 |
| 15 | 22 | Wang Laboratories | 273.6 | 113.8% | 8.9% | 79.8% | 3,068.4 | 6/88 |
| 16 | 23 | Compaq Computer | 273.5 | 141.5% | 13.2% | 89.9% | 2,065.6 | 12/88 |
| 17 | 13 | Litton Industries | 230.1 | -5.2% | 4.7% | 64.6% | 4,863.9 | 7/88 |
| 18 | 17 | AMP | 220.3 | 28.2% | 8.2% | 59.6% | 2,699.7 | 12/88 |
| 19 | 25 | National Semiconductor | 198.9 | 110.0% | 8.1% | 85.5% | 2,469.7 | 5/88 |
| 20 | 20 | Tandem Computers | 185.1 | 30.0% | 14.1% | 102.6% | 1,314.7 | 9/88 |
| 21 | 15 | Control Data | 169.8 | -4.8% | 4.7% | 86.6% | 3,628.3 | 12/88 |
| 22 | 27 | Apple Computer | 144.0 | 67.2% | 3.5% | 32.9% | 4,071.4 | 9/88 |
| 23 | 24 | Prime Computer | 140.9 | 40.2% | 8.8% | 80.6% | 1,594.6 | 12/88 |
| 24 | 31 | Sun Microsystems | 117.3 | 54.2% | 11.2% | 100.0% | 1,051.6 | 6/88 |
| 25 | 16 | LSI Logic | 101.0 | -42.1% | 26.6% | 128.5% | 378.9 | 12/88 |
| 26 | 21 | Advanced Micro Devices | 97.7 | -29.1% | 8.7% | 56.7% | 1,125.9 | 12/88 |
| 27 | 19 | Data General | 96.6 | -32.4% | 7.1% | 116.6% | 1,364.7 | 9/88 |
| 28 | 26 | Tandy | 94.2 | 1.1% | 2.5% | 28.1% | 3,793.8 | 6/88 |
| 29 | 33 | Perkin-Elmer | 83.6 | 25.7% | 7.2% | 94.9% | 1,165.5 | 7/88 |
| 30 | 49 | Cray Research | 82.0 | 104.3% | 10.8% | 29.5% | 756.3 | 12/88 |
| 31 | 28 | Harris | 81.2 | -2.9% | 3.9% | 47.9% | 2,099.3 | 6/88 |
| 32 | 32 | Tektronix | 78.1 | 16.9% | 5.5% | 164.9% | 1,411.9 | 5/88 |
| 33 | 35 | Microsoft | 71.6 | 23.5% | 12.1% | 51.2% | 590.8 | 6/88 |
| 34 | 41 | Molex | 68.7 | 38.9% | 13.7% | 68.5% | 502.4 | 6/88 |
| 35 | 45 | Intergraph | 66.5 | 52.3% | 8.3% | 54.3% | 800.2 | 12/88 |
| 36 | 63 | Micropolis | 64.0 | 186.8% | 18.1% | -1,354.1% | 353.1 | 12/88 |
| 37 | 37 | Apollo Computer | 60.3 | 12.3% | 9.2% | 141.7% | 653.5 | 12/88 |
| 38 | 34 | General Instrument | 60.0 | -5.0% | 5.2% | 46.2% | 1,155.5 | 2/88 |
| 39 | 58 | Applied Magnetics | 55.5 | 115.5% | 18.9% | 137.8% | 293.0 | 9/88 |
| 40 | 57 | Lotus Development | 55.2 | 107.5% | 11.8% | 57.4% | 468.5 | 12/88 |
| 41 | 40 | VLSI Technology | 55.2 | 10.1% | 24.9% | 149.4% | 221.2 | 12/88 |
| 42 | 38 | E-Systems | 53.7 | 5.1% | 3.7% | 57.6% | 1,443.1 | 12/88 |
| 43 | 50 | Loral | 50.9 | 49.1% | 3.5% | 38.6% | 1,440.8 | 3/88 |
| 44 | 46 | Analog Devices | 47.3 | 9.9% | 10.8% | 63.4% | 439.2 | 10/88 |
| 45 | 14 | Storage Technology | 47.2 | -73.7% | 5.4% | 35.7% | 874.0 | 12/88 |
| 46 | 62 | DSC Communications | 45.9 | 97.7% | 13.5% | 103.0% | 339.7 | 12/88 |
| 47 | — | Micron Technology | 44.3 | 877.6% | 14.7% | 35.9% | 300.5 | 8/88 |
| 48 | 44 | Varian Associates | 43.2 | -6.5% | 3.7% | 69.2% | 1,170.6 | 9/88 |
| 49 | 52 | SCI Systems | 42.8 | 44.6% | 5.5% | 110.3% | 777.7 | 6/88 |
| 50 | 68 | Maxtor | 38.1 | 118.8% | 14.1% | 153.0% | 271.2 | 3/88 |

(Continued)

## Top U.S. capital spenders

| Rank 1988 | Rank 1987 | Company | Total capital expenditures ($ millions) | Change from 1987 | Capital expenditures as a percentage of revenue | Capital expenditures to net cash flow after dividends | Fiscal 1988 revenue ($ millions) | Fiscal year ended |
|---|---|---|---|---|---|---|---|---|
| 51 | 61 | Sprague Technologies | $38.1 | 56.8% | 7.6% | 80.7% | $504.6 | 12/88 |
| 52 | — | Ashton-Tate | 36.4 | 459.4% | 11.8% | 52.0% | 307.3 | 1/89 |
| 53 | 48 | Western Digital | 35.9 | -11.6% | 4.7% | 50.1% | 768.3 | 6/88 |
| 54 | 55 | Medtronic | 33.5 | 18.0% | 5.1% | 33.0% | 653.3 | 4/88 |
| 55 | 36 | Zenith Electronics | 32.9 | -40.6% | 1.2% | 68.0% | 2,685.7 | 12/88 |
| 56 | 51 | AVX | 32.5 | 2.2% | 8.0% | 61.0% | 408.9 | 12/88 |
| 57 | 70 | Oracle Systems | 31.0 | 83.3% | 11.0% | 55.4% | 282.1 | 5/88 |
| 58 | — | Conner Peripherals | 30.4 | 75.5% | 11.8% | 122.5% | 256.6 | 12/88 |
| 59 | 73 | Mentor Graphics | 29.3 | 99.3% | 9.7% | 62.6% | 300.8 | 12/88 |
| 60 | 64 | Bolt Beranek and Newman | 28.8 | 29.8% | 9.4% | 84.9% | 305.2 | 6/88 |
| 61 | — | Integrated Device Technology | 27.9 | 59.3% | 23.0% | 110.8% | 121.1 | 3/88 |
| 62 | 43 | Avnet | 24.7 | -47.8% | 1.4% | 38.9% | 1,829.3 | 6/88 |
| 63 | 56 | M/A-COM | 23.2 | -13.4% | 5.5% | 58.8% | 424.2 | 9/88 |
| 64 | — | Burr-Brown | 21.3 | 89.6% | 12.1% | 83.1% | 176.7 | 12/88 |
| 65 | — | Wyse Technology | 20.8 | 157.8% | 4.6% | 59.5% | 456.6 | 3/88 |
| 66 | — | Concurrent Computer | 20.4 | 42.7% | 7.8% | 72.8% | 263.1 | 6/88 |
| 67 | 86 | Applied Materials | 19.8 | 72.5% | 5.5% | 38.5% | 362.8 | 10/88 |
| 68 | 47 | Teradyne | 19.8 | -51.7% | 4.3% | 75.9% | 462.3 | 12/88 |
| 69 | 59 | Datapoint | 19.6 | -23.3% | 5.9% | 82.2% | 330.8 | 7/88 |
| 70 | — | 3Com | 18.9 | 201.5% | 7.5% | 61.7% | 251.9 | 5/88 |
| 71 | 92 | Computer Associates | 18.9 | 80.6% | 2.7% | 11.8% | 709.1 | 3/88 |
| 72 | 75 | LTX | 18.1 | 33.0% | 10.3% | 89.4% | 174.8 | 7/88 |
| 73 | 74 | Stratus Computer | 17.8 | 28.8% | 6.7% | 43.4% | 265.3 | 12/88 |
| 74 | 71 | Cherry | 17.8 | 15.0% | 9.1% | 92.2% | 194.6 | 2/88 |
| 75 | 53 | Augat | 17.7 | -39.8% | 5.5% | -147.8% | 321.0 | 12/88 |
| 76 | 78 | MAI Basic Four | 16.4 | 24.7% | 3.9% | 63.5% | 420.8 | 9/88 |
| 77 | 76 | Kollmorgen | 15.8 | 16.8% | 4.6% | 65.3% | 344.8 | 12/88 |
| 78 | 100 | Fluke | 15.7 | 89.1% | 7.0% | 68.2% | 224.5 | 9/88 |
| 79 | 90 | Gerber Scientific | 15.4 | 45.7% | 5.8% | 44.9% | 264.0 | 4/88 |
| 80 | — | Novell | 15.3 | -28.0% | 5.5% | 40.4% | 281.2 | 10/88 |
| 81 | 80 | Dynatech | 15.1 | 20.0% | 4.1% | 39.5% | 367.8 | 3/88 |
| 82 | — | AST Research | 14.6 | 132.8% | 3.5% | 67.9% | 412.7 | 6/88 |
| 83 | 67 | Digital Communications | 13.6 | -28.1% | 6.0% | 26.5% | 227.5 | 6/88 |
| 84 | 87 | ADC Telecommunications | 13.5 | 21.2% | 7.5% | 51.7% | 179.9 | 10/88 |
| 85 | — | International Rectifier | 12.9 | 114.6% | 7.2% | -8,571.5% | 178.6 | 6/88 |
| 86 | 84 | Andrew | 12.8 | 10.3% | 5.1% | 46.1% | 253.5 | 9/88 |
| 87 | 85 | Sanders | 12.4 | 7.3% | 6.0% | 119.1% | 205.9 | 12/88 |
| 88 | 94 | Gencorp | 12.2 | 29.9% | 4.2% | 87.3% | 291.4 | 12/88 |
| 89 | 81 | Watkins-Johnson | 11.6 | -5.7% | 4.0% | 39.4% | 292.2 | 12/88 |
| 90 | 91 | Westmark International | 11.3 | 7.2% | 3.1% | 54.1% | 365.3 | 12/88 |
| 91 | 95 | Marshall Industries | 10.8 | 17.4% | 2.6% | 55.1% | 420.4 | 5/88 |
| 92 | — | Diasonics | 10.5 | 30.4% | 3.7% | 52.8% | 281.6 | 12/88 |
| 93 | — | Measurex | 10.3 | 48.5% | 3.9% | 23.5% | 265.2 | 11/88 |
| 94 | — | Scientific-Atlanta | 10.1 | 50.5% | 2.0% | 25.1% | 508.6 | 6/88 |
| 95 | 77 | CTS | 10.0 | -25.1% | 3.6% | 49.2% | 275.6 | 12/88 |
| 96 | — | Wyle Laboratories | 9.4 | 148.8% | 2.3% | 93.0% | 410.9 | 1/89 |
| 97 | 98 | Coherent | 9.1 | 6.8% | 4.8% | 159.0% | 188.1 | 9/88 |
| 98 | 65 | Recognition Equipment | 9.0 | -58.2% | 3.5% | 87.5% | 260.8 | 10/88 |
| 99 | — | Mark IV Industries | 9.0 | 68.0% | 2.2% | 31.9% | 403.0 | 2/88 |
| 100 | 69 | Cable | 7.0 | -59.1% | 1.9% | 50.3% | 364.9 | 9/88 |

(Continued)

# Top U.S. capital spenders by segment

## Capital equipment

| Capital expenditures FY 1988 | Total ($ millions) | Change from 1987 |
|---|---|---|
| Hewlett-Packard | $648.0 | 27.8% |
| Perkin-Elmer | 83.6 | 25.7% |
| Tektronix | 78.1 | 16.9% |
| Applied Materials | 19.8 | 72.5% |
| Teradyne | 19.8 | -51.7% |
| LTX | 18.1 | 33.0% |
| Fluke | 15.7 | 89.1% |
| Gerber Scientific | 15.4 | 45.7% |
| GenRad | 12.4 | 7.3% |
| **Total, weighted avg.** | **$910.9** | **23.6%** |

## Communications

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Motorola | $873.0 | 32.7% |
| General Instrument | 60.0 | -5.0% |
| DSC Communications | 45.9 | 97.7% |
| Bolt Beranek and Newman | 28.8 | 29.8% |
| Datapoint | 19.6 | -23.3% |
| 3Com | 18.9 | 201.5% |
| Novell | 15.3 | -28.0% |
| Dynatech | 15.1 | 20.0% |
| Digital Communications | 13.6 | -28.1% |
| ADC Telecommunications | 13.5 | 21.2% |
| Andrew | 12.8 | 10.3% |
| Scientific-Atlanta | 10.1 | 50.5% |
| **Total, weighted avg.** | **$1,126.7** | **27.9%** |

## Components

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| AMP | $220.3 | 28.2% |
| Molex | 68.7 | 38.9% |
| Sprague Technologies | 38.1 | 56.8% |
| AVX | 32.5 | 2.2% |
| Cherry Electrical | 17.8 | 15.0% |
| Augat | 17.7 | -39.8% |
| CTS | 10.0 | -25.1% |
| **Total, weighted avg.** | **$405.0** | **20.7%** |

## Computer-based systems

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Hewlett-Packard | $648.0 | 27.8% |
| Intergraph | 66.5 | 52.3% |
| Mentor Graphics | 29.3 | 99.3% |
| Gerber Scientific | 15.4 | 45.7% |
| Measurex | 10.3 | 48.5% |
| Coherent | 9.1 | 6.8% |
| Recognition Equipment | 9.0 | -58.2% |
| **Total, weighted avg.** | **$787.6** | **28.5%** |

## Distribution

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Avnet | $24.7 | -47.8% |
| Marshall Industries | 10.8 | 17.4% |
| Wyle Laboratories | 9.4 | 148.8% |
| **Total, weighted avg.** | **$44.9** | **-25.5%** |

## Government

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Motorola | $873.0 | 32.7% |
| Texas Instruments | 628.1 | 35.7% |
| GM Hughes Electronics | 533.0 | 13.5% |
| Honeywell | 327.7 | 7.7% |
| Litton Industries | 230.1 | -5.2% |
| Harris | 81.2 | -2.9% |
| E-Systems | 53.7 | 5.1% |
| Loral | 50.9 | 49.1% |
| Varian Associates | 43.2 | -6.5% |
| SCI Systems | 42.8 | 44.6% |
| M/A-COM | 23.2 | -13.4% |
| Watkins-Johnson | 11.6 | -5.7% |
| Cubic | 7.0 | -59.1% |
| **Total, weighted avg.** | **$2,905.5** | **19.2%** |

## Mainframes

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| IBM | $5,390.0 | 25.2% |
| Unisys | 669.9 | -7.1% |
| NCR | 420.4 | 8.0% |
| Amdahl | 278.9 | 76.8% |
| Control Data | 169.8 | -4.8% |
| Cray Research | 82.0 | 104.3% |
| **Total, weighted avg.** | **$7,011.0** | **21.1%** |

## Medical

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Medtronic | $33.5 | 18.0% |
| Westmark International | 11.3 | 7.2% |
| Diasonics | 10.5 | 30.4% |
| **Total, weighted avg.** | **$55.3** | **17.7%** |

## Microcomputers

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| IBM | $5,390.0 | 25.2% |
| Compaq Computer | 273.5 | 141.5% |
| Apple Computer | 144.0 | 67.2% |
| Tandy | 94.2 | 1.1% |
| Zenith Electronics | 32.9 | -40.6% |
| AST Research | 14.6 | 132.8% |
| **Total, weighted avg.** | **$5,949.1** | **27.7%** |

## Minicomputers

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| IBM | $5,390.0 | 25.2% |
| Digital Equipment | 1,517.6 | 102.8% |
| Hewlett-Packard | 648.0 | 27.8% |
| Tandem Computers | 185.1 | 30.0% |
| Prime Computer | 140.9 | 40.2% |
| Sun Microsystems | 117.3 | 54.2% |
| Data General | 96.6 | -32.4% |
| Apollo Computer | 60.3 | 12.3% |
| Concurrent Computer | 20.4 | 42.7% |
| Stratus Computer | 17.8 | 28.8% |
| MAI Basic Four | 16.4 | 24.7% |
| **Total, weighted avg.** | **$8,210.5** | **34.2%** |

## Office equipment

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| IBM | $5,390.0 | 25.2% |
| Xerox | 1,399.0 | 49.3% |
| NCR | 420.4 | 8.0% |
| Pitney Bowes | 309.5 | 22.9% |
| Wang Laboratories | 273.6 | 113.8% |
| Harris | 81.2 | -2.9% |
| **Total, weighted avg.** | **$7,873.6** | **29.2%** |

## Peripherals

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Seagate Technology | $284.4 | 262.8% |
| Micropolis | 64.0 | 185.8% |
| Applied Magnetics | 55.5 | 115.5% |
| Storage Technology | 47.2 | -73.7% |
| Maxtor | 38.1 | 118.8% |
| Conner Peripherals | 30.4 | 75.5% |
| Wyse Technology | 20.8 | 157.8% |
| AST Research | 14.6 | 132.8% |
| Genicom | 12.2 | 29.9% |
| **Total, weighted avg.** | **$567.1** | **55.8%** |

## Semiconductors

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Motorola | $873.0 | 32.7% |
| Texas Instruments | 628.1 | 35.7% |
| Intel | 477.5 | 58.3% |
| National Semiconductor | 198.9 | 110.0% |
| LSI Logic | 101.0 | -42.1% |
| Advanced Micro Devices | 97.7 | -29.1% |
| VLSI Technology | 55.2 | 10.1% |
| Analog Devices | 47.3 | 9.9% |
| Micron Technology | 44.3 | 877.6% |
| Western Digital | 35.9 | -11.6% |
| Integrated Device Tech. | 27.9 | 59.3% |
| Burr-Brown | 21.3 | 89.6% |
| International Rectifier | 12.9 | 114.6% |
| **Total, weighted avg.** | **$2,620.9** | **30.9%** |

## Software

| | Total ($ millions) | Change from 1987 |
|---|---|---|
| Microsoft | $71.6 | 23.5% |
| Lotus Development | 55.2 | 107.5% |
| Ashton-Tate | 36.4 | 459.4% |
| Oracle Systems | 31.0 | 83.3% |
| Computer Associates | 18.9 | 80.6% |
| **Total, weighted avg.** | **$213.0** | **79.9%** |

Source: ELECTRONIC BUSINESS

# Foot dragging in U.S. slows ATE market growth

*ATE sales rose a deceptive 21% in 1988, with the strong growth coming in the Far East. U.S. chip makers don't figure to buy big in 1989 either*

BY TAMMI HARBERT

The worldwide market for automatic test equipment had a good year in 1988, although many ATE companies didn't know it. The market's 21% growth in 1988 was selective both by type of ATE and by geography. Much of the growth — attributed principally to the memory chip tester arena — took place not in the mature U.S. market, but in the Far East.

While 1988 growth was deceptive, signs are pointing to a flat 1989. Nonetheless, at least two companies, Hewlett-Packard Co. in Palo Alto, Calif., and Tektronix Inc. in Beaverton, Ore., are insistent on expanding their ATE offerings into production-oriented integrated-circuit (IC) tests. Other companies have made entrees into the diagnostic systems business with electronic-beam equipment. Still other ATE firms are pointing to boundary-scan test techniques as future growth areas.

The biggest general increase in 1988 ATE purchases came in Japan, where the consumption rate grew 45% over 1987, more than twice as fast as the worldwide growth rate, according to analyst Kenneth Neff, vice president at Prime Data, a market-research company in San Jose. Japan accounted for a significant portion of the 31.8% growth in the semiconductor-test area, Neff estimates.

Although Prime Data has not yet calculated its official 1989 forecasts, the company projects flat ATE growth for the year. Growth in worldwide sales could be −5% to −10% for semiconductor testers and 0% to 5% for board testers, according to Neff.

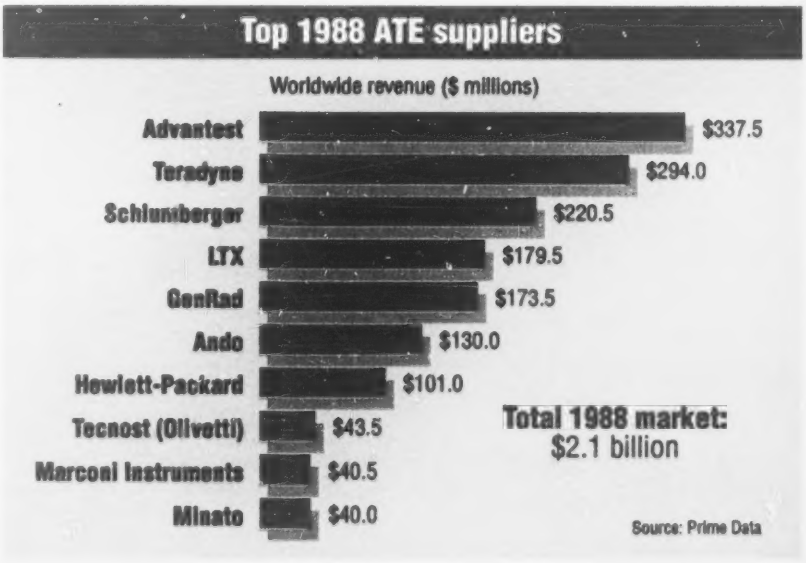
The downturn in IC testers in 1989 can be attributed to a flatter computer market and to the assumption that memory tester sales cannot continue at their high 1988 growth rates. Given the general fear about recession, companies are being more cautious about large capital spending decisions, Neff says.

U.S. semiconductor manufacturers did not buy much test equipment last year and don't intend to this year, according to Frederick Van Veen, vice president of corporate relations for Teradyne Inc. in Boston, a supplier of both component and board testers. U.S. merchant semiconductor manufacturers "are really dragging their feet on cutting purchase orders," says Van Veen, who interprets this inaction as a "lack of conviction by manufacturers about retooling their factories."

Teradyne's total revenue jumped from $55 million to $90 million in the Far East market between 1987 and 1988, Van Veen says, almost entirely due to semiconductor-tester sales. In the United States, Teradyne's total sales grew only about 10%, from $229 million to $251 million; and in Europe, 30%, from $84 million to $109 million, primarily from ATE. The demand is reflected in the company's inventory: Teradyne has a 20- to 26-week leadtime in memory testers, but only an eight- to 12-week leadtime for very large scale integration (VLSI) testers.

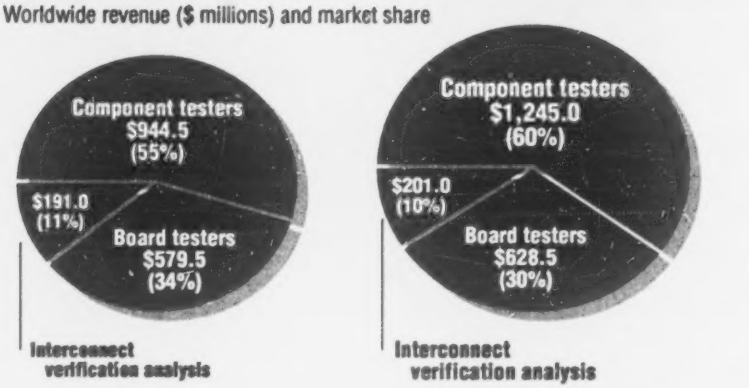
### Increased activity?

Craig Foster, vice president of marketing at Megatest Corp. in San Jose, a $40 million private company that sells logic and memory IC testers, argues that, on the contrary, there is increased activity among U.S. semiconductor makers. Megatest's largest customer worldwide is Micron Technology Inc. in Boise, Idaho, which had total 1988 revenue of $367.7 million and net income of $121.7 million. Many U.S. companies are interested in starting DRAM production in this country,



## 1988 ATE market segments

Worldwide revenue ($ millions) and market share




Source: Prime Data

Foster says. In June, for example, the Semiconductor Industry Association gave its blessing to the formation of a corporation to produce DRAMs, called U.S. Memories Inc. Initial supporters include IBM, Digital Equipment Corp., Hewlett-Packard, and Intel Corp.

Megatest also has a strong market position in Korea, Foster says, where he estimates the company sells about 30% of its machines. The company does not yet sell to Japan, although it has formed partnerships there and is in the process of entering that market. Foster projects 50% growth in memory tester sales, which is a conservative estimate, he says.

The surge in memory tester sales combined with the growing consumption in Japan are major reasons why Advantest Corp., a Japanese company, moved to the No. 1 position in worldwide ATE revenue in 1988. The strongest growth over the next three years for IC testers is expected to come in the Pacific Rim, according to Hiroji Agata, national sales manager for Advantest America Inc. in Lincolnshire, Ill. Korea and Taiwan, both developing quickly in memory production, will increase their capital expenditures by 100% or more each year for the next two years, he says. For example, Korea spent $13 million on ATE equipment in 1988 and is expected to spend $42 million in 1989 and $80 million in 1990. In contrast, Agata expects 10% growth in the United States market over the next three years.

Beyond memory testers, however, most IC-tester companies cite moderate to slow growth. For 1989, the market for VLSI testers could be off by 10% to 20%, says Stephen Balog, senior vice president at Shearson Lehman Hutton Inc. He attributes the downturn to a need for the industry to "sit back and belch" after heavy consumption in 1988.

In addition, he says, the semiconductor test market has a perennial problem: because it is such a small market, with only 20 or so companies that buy VLSI testers, test companies are tied too closely to the cycles of the semiconductor industry. LTX Corp. in Westwood, Mass., for example, experienced severe losses this year. This was principally due to losing orders from Intel, which had been buying $10 million worth of ATE a quarter from LTX. Suddenly in January 1989, it stopped, because of a softening demand for chips and an increase in Intel's chip yields. Consequently, LTX's quarterly revenue fell from $48 million to $25 million over three consecutive quarters, translating into a $19 million loss in the quarter ending April 1989, says Balog. In addition to the problem of a narrow market, there are simply too many companies in the IC-tester business, he says. "We really just need to have some companies go away."

**Japan's ATE purchases increased 45% in 1988**

On the other hand, Hewlett-Packard and Tektronix have been seeking to expand their IC test business. While for years Tektronix had been manufacturing a high-end device-characterization machine used in engineering environments, only two years ago did it enter the IC tester area. HP has been offering a high-performance analog and mixed-signal IC tester, also for two years, as well as a digital IC tester for design evaluation. Both companies cite their test and measurement expertise as business advantages and both plan to expand their product offerings.

### Board testers: moderate growth

In contrast to the dramatic ups and downs of the component test business, the market for board testers had moderate growth last year and is so far holding steady this year. The board tester market has never experienced the dramatic shifts of the IC-test industry, Balog says, because it has a much broader customer base. However, companies are seeing business shift this year among several segments of the market, and they worry that a general economic slowdown could affect capital spending.

Board tester vendors have watched in fear as one after another of the minicomputer makers, including DEC, have reported disappointing 1989 revenue. Bob Anderson, president and CEO of GenRad Inc. in Concord, Mass., says business is holding steady, but "we and other companies are taking a cautious look toward the future." The workstation and PC markets are still healthy, he says. On balance, GenRad expects 1989 sales to increase 5%.

Teradyne saw sales of its high-end board testers, used mostly by the military, taper off in the second quarter. But vice president Van Veen isn't sure lower defense spending necessarily indicates a permanent lessening of demand in that sector. With slower military spending, he posits, the government may spend relatively more on electronics to refurbish older planes and tanks.

In the board test market, several companies report a shift away from

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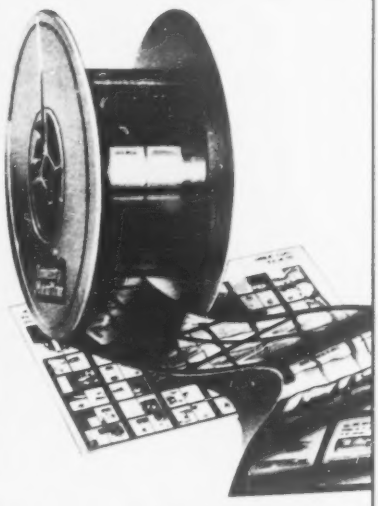

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in-circuit testing, which checks that all devices are placed on boards properly, and toward more functional testing, because of the increasing complexity of boards. That sector's growth could be 20% to 40% over the next two to three years, estimates Rick Henninger, director of marketing for Computer Automation Inc. in Irvine, Calif., a $22 million company whose ATE division specializes in high-performance functional testing. The company's functional testers are becoming less expensive and are taking less time to program, according to Jack Ferguson, director of sales.

But some companies believe functional testing may still be too expensive and time consuming to develop the software. HP, which has been in the board-test business for about 10 years, specializes in in-circuit testers with some functional capability. HP is offering a tester that is a combination of the two types, believing that is where most market growth will take place, notes Ned Barnholt, vice president and general manager of the company's electronic-instrument group. Combinational, he says, is more cost effective than functional.

The distinctions between in-circuit testers and functional testers are becoming so blurred that GenRad, the market leader in board testers, prefers to use its own classifications: process testers and performance testers. Process testers verify the board-manufacturing process and generally cost $100,000 to $500,000, according to president Anderson. Performance testers, which ensure the board functions correctly, cost $400,000 to more than $1 million. GenRad commands 32% of the market for in-circuit testers and 16% of the market for functional testers, according to Prime Data.

**Bright spots**

Several companies are pointing to diagnostic systems business with electronic-beam equipment as a promising area. Schlumberger Technologies in San Jose, a unit of Schlumberger Ltd., started its diagnostic business in 1987, notes Steve Harari, vice president of marketing. These diagnostic machines use electronic beams to probe IC components. Schlumberger is projecting strong growth for these systems. For example, while the company derived 10% of its revenue from diagnostic systems in 1988, it expects 15% in 1989. The company has already witnessed the increase over the first two quarters of 1989, Harari notes.

Advantest has also recently entered the E-beam business. The company sees an increasing market for such systems because of the decreasing geometries of ICs, according to Keith Lee, engineering manager for Advantest America. Below 1 micron, he says, traditional probing is no longer possible. Although the company has earned no revenue from this business yet, it is projecting that at least 10% of its revenue will come from E-beams over the next two years, national sales manager Agata says.

Another area of growth could be in machines that take advantage of boundary-scan test techniques. In May, Motorola Inc.'s application-specific integrated circuit (ASIC) division and Schlumberger's ATE division announced an $8 million agreement to develop a digital-component tester that would incorporate boundary scan. A prototype is expected in October, and delivery of five systems to Motorola is expected in the third quarter of 1990.

**Beyond memory testers, most IC-tester companies cite moderate growth to slow growth**

GenRad's Anderson agrees that boundary scan will become an important part of future ATE systems. The adoption of a standard boundary-scan technique, proposed by the Joint Test Action Group, an organization established in 1986 in Europe, will make it easier for ATE companies to justify the R&D investments to develop effective diagnostic software, he says. However, it will take five to 10 years before all chips incorporate boundary-scan features, he adds.

The incorporation of boundary scan in the short term will require that features be added to ATE systems, Anderson says. In the long term, if there are boards consisting completely of chips with boundary scan, he predicts, then less expensive ATE systems will be possible. ☐

# Fast-blooming CVD market: Equipment makers' bright spot

*As hot new consumer markets are fueling the demand for complex chips that require CVD processes, U.S. companies fight for market share*

BY JOYCE A. CONNELLEY

Investors shopping for bargains in the electronics industry should take a long, hard look at the U.S.-dominated chemical vapor deposition market. In the midst of a somewhat depressed equipment market, CVD offers investors a bright spot on the horizon, one that ultimately may draw fierce competition from overseas rivals.

In fact, the CVD market fielded the only two equipment companies to go public in the last four years: Novellus Systems Inc. and Genus Inc., both of which went public in 1988.

Why all the excitement? Hot new markets for facsimile machines, car phones and even high-definition television are fueling demand for increasingly complex chips. Such products are complex enough to require several levels of interconnecting circuits, which, in turn, require a chemical vapor deposition process. CVD is a process by which a layer of either conductive or insulative material is placed on a silicon wafer to connect two or more levels of circuitry, doing so without the glitches or flaws of older furnace diffusion or sputtering techniques.

The CVD market grew 88% in 1988 over 1987, rising from $278.5 million to $523.2 million. That compares with an earlier compound annual growth rate of 28% between 1984 and 1987, according to VLSI Research Inc., San Jose, a market research firm that tracks the CVD market.

Compounded annually, CVD, which makes up 6% of the semiconductor equipment manufacturing (SEM) market, is expected to return to a relatively sedate 21.5% average growth between 1988 and 1993. But by comparison, according to VLSI Research figures, the rest of the SEM market — worth $8.2 billion in 1988 — will show a 14.8% compound annual growth rate through the same period.

A handful of players, including Genus, Novellus Systems and Applied Materials Inc., currently dominate the market, but the consensus among analysts and executives is that CVD will be a tempting target for the Japanese, prompting potentially fierce competition in the future.

Right now, though, that competition seems to be limited to which version of CVD — insulative or conductive — will be the flavor of the day, as the Americans battle to determine who comes out on top.

VLSI Research divides the CVD market into four key segments: atmospheric; low pressure; plasma enhanced; and photo. The largest segment is plasma enhanced at $231 million, followed closely by low pressure CVD at $226.8 million. Atmospheric equipment totals an estimated $63.4 million, while photo CVD, still in early experimental stages, represents only about 0.4% of the market at an estimated $2 million.

But Genus' CEO William Elder divides the market by whether the material to be deposited is insulative (dielectric) or conductive. Mountain View, California-based Genus' products are designed for conductive applications, which include parts of both the low pressure and the embryonic photo CVD markets. But the market's size is elusive. "It all boils down to speed and density," Elder says. "The only way you can get that is through more planarization."

Novellus Systems of San Jose has

**William Elder, Genus' CEO: "Our competition is Japan, and we have to beat them in Japan"**

Larry Echelle

focused exclusively on the plasma enhanced segment, while Applied Materials of Santa Clara, Calif., has tried to build a machine capable of handling a variety of processes.

In a fast growing market such as CVD, the faces of competitors change as fast as the technology. This year, Applied Materials and Novellus Systems are two of the three fastest growing companies in CVD, says Dan Hutcheson, president of VLSI Research. The third is Genus. However, Hutcheson notes that in 1982, when CVD was in its infancy, none of those three firms had a presence in the market. "Every four or five years, you have a whole new set of competitors," he says.

Applied Materials offers a good example: in only two years it went from being a virtual nonplayer in the CVD market to creating an entire CVD division, representing 25% of the firm's total revenue, says David Wang, vice president and general manager of the CVD product division. Applied Materials had been in the CVD sector in the 1970s but dropped out only to re-enter. In 1988, the division's revenue topped $100 million, while the company as a whole reported $363 million.

The two start-ups, Genus and Novellus, have even more impressive revenue figures. Genus reported a 263% growth spurt from 1987's $15 million in revenue to more than $55 million in 1988. Novellus Systems' net sales leaped from $3.2 million in 1987 to $23.2 million in 1988, a 625% annual growth rate.

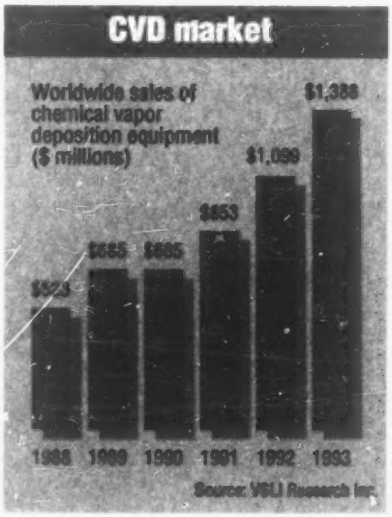
But those three firms are not alone in the market, nor are they largest. Advanced Semiconductor Materials International N.V. of The Netherlands, with U.S. offices in Phoenix, Ariz., boasts the biggest slice at nearly 20% of the market, according to VLSI Research. ASM's sales revenue in 1988 was $180 million; 64% of that total was derived from its CVD sector. Applied Materials holds about 15% of the CVD marketplace. Shares for Genus and Novellus Systems are estimated at 8% and 5%, respectively.

### Foreign fears

Hanging on to those percentages will be difficult, even in such a burgeoning market, as other CVD competitors, mainly the Japanese, are poised to wrestle some of that share away. Among the U.S. firms expected to enter the fray is LAM Research Corp., Fremont, Calif., which recently acquired San Diego-based Monkowski-Rhine, a CVD equipment developer.

According to Robert Graham, Novellus Systems' CEO, Japanese manufacturers have had problems competing in the SEM market because their operations are geared toward mass production, while semiconductor equipment is manufactured in very small quantities.

Hutcheson of VLSI Research notes that foreign competition over the last two years has "not been that strong." But at the same time, he points out, American firms have lost market share to overseas competitors. In the early 1980s the United States dominated the SEM market with an 80% share; that has fallen to 49% in 1988, according to Hutcheson.




Wang of Applied Materials counters with figures from Dataques, Inc., a market research firm, that indicate the Japanese have actually lost market share in certain segments of semiconductor equipment manufacturing. "In ion implantation and photo lithography, the Japanese have gained market share, but they've lost ground in CVD," Wang says.

Genus' Elder, however, is deeply concerned about competition from Japan. "Our competition is Japan, and we have to beat them in Japan," he says.

Europe, on the other hand, Elder says, is an "emerging" market American companies can still take advantage of.

"Companies like Genus need to be very strong internationally to succeed," Elder says. "Clearly, you need to be involved in the global marketplace because that's going to drive your future." He adds: "If you're only selling in the U.S., you're probably losing market share."

The CVD process has become so important to the semiconductor industry that some customers say it will soon make some manufacturing methods obsolete. Joe Zelayeta, vice president for manufacturing for LSI Logic Corp., Milipitas, Calif., says all semiconductor products his company turns out rely on CVD.

"Our business is very interconnect intensive," Zelayeta explains. "You have to use CVD to provide insulation between the layers."

Jack Saltich, vice president and general manager of San Jose-based VLSI Technology Inc.'s memory and technology division, says his company uses CVD processes exclusively in manufacturing.

Graham of Novellus Systems says another method that may soon be history is the depletion process. Through depletion, gas is introduced at a single point and allowed to spread out over the wafer. However, as it spreads, the gas weakens, resulting in a nonuniform layer. Graham maintains that the depletion process will be replaced by plasma enhanced CVD.

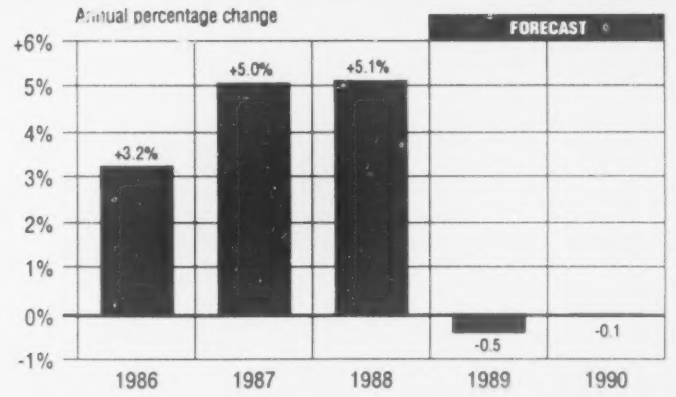
### CVD's lifespan

A significant, long-range problem facing CVD equipment manufacturers is, for the moment, being ignored: How long can the industry rely on the rapid growth brought about by the technological advancements in semiconductor design? The answer seems to be: not terribly long.

According to Graham, "This market segment will continue to outperform the rest of the industry for another three to four years or so."

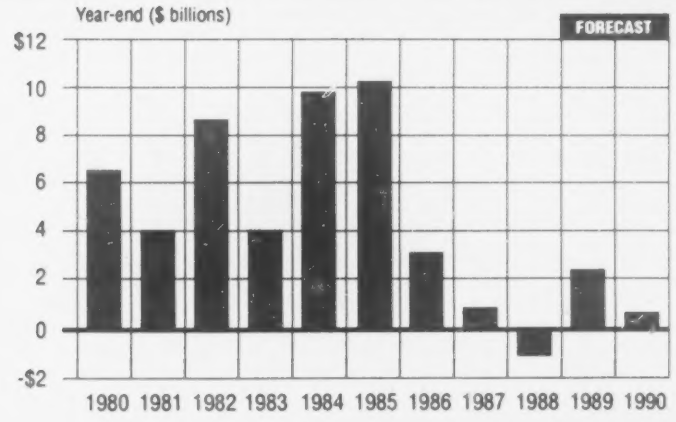
The rough prediction is that CVD will serve the semiconductor manufacturing industry beyond that time frame, but, sooner or later, another technology will surge to the forefront and supplant CVD. "Ten years ago, we saw it in lithography, and five years ago, we saw it in etch," says Graham. "Now we're seeing it in CVD." □

## Communications equipment shipments



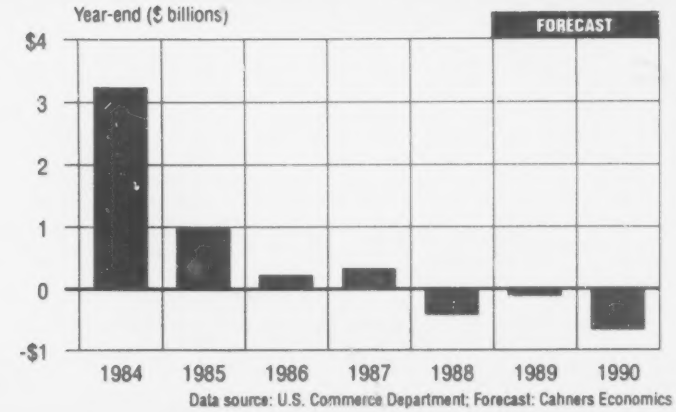

Data source: U.S. Commerce Department; Forecast: Cahners Economics

## Communications equipment: Change in backlog




Data source: U.S. Commerce Department; Forecast: Cahners Economics

## Communications equipment: Change in inventory




Data source: U.S. Commerce Department; Forecast: Cahners Economics

# Slowdown won't hurt communications too much

New orders for communication equipment fell in May, declining 3.2% from April to total just under $6 billion. Weakness was most evident in the defense portion of the industry, but even on the less volatile commercial side, growth in new orders started to recede in mid-1988. Decreased demand for the products means shipments gains will be less.

Cahners Economics is forecasting a 0.5% drop in U.S. factory shipments for the total communication equipment industry in 1989 and flat growth in 1990. The turnaround for the industry is expected to start again by the third quarter of next year, so psychologically 1990 will be more upbeat as the industry begins to see demand pick up again.

One positive factor helping to stabilize this industry during the current economic slowdown is its relatively high level of backlogs. As of May, unfilled orders amounted to $64 billion, of which approximately three-fourths were for defense-related equipment. Although the military buildup of the early decade has given defense contractors a buffer, backlogs have been steadily shrinking. The current level represents a drop of 3% from a year ago.

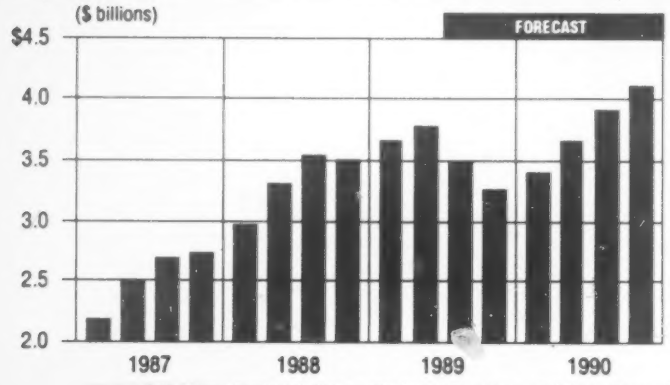
Furthermore, the industry is not going to experience as severe an inventory correction as it did in 1986 and 1987. In fact, during 1988 inventory continued to decline from the year before and has only recently started to edge up. No large inventory overhang means the industry is in better shape to weather the business cycle downturn.

A third factor working to keep the industry contraction from becoming a total disaster is the value of the dollar and the opening of some export markets to U.S. telecommunication equipment. Based on data from the American Electronics Association, exports of telecommunication equipment were still growing at a rapid pace. In the first quarter of this year, exports reached $1.21 billion, up 24.9% compared with a year ago. Even though the dollar has come back from its most recent low, particularly versus the yen and deutsche mark, it is still well below its peak of 1985. So, expect continued growth in exports, although at reduced rates.

MADELINE FRANCHI

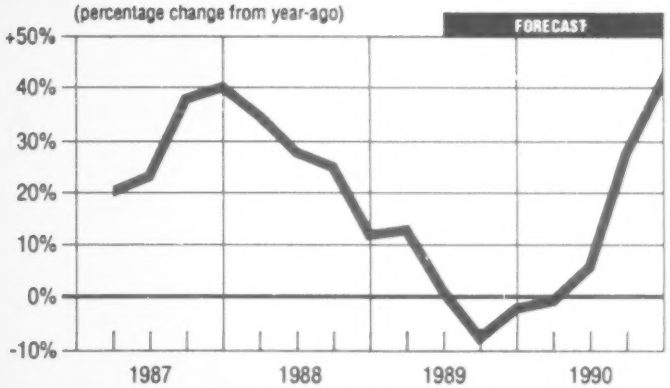
*A column on communication equipment will appear again in the November 27th issue.*

## Semiconductor sales to North America




Data source: Semiconductor Industry Association; Forecast: Cahners Economics

## Semiconductor bookings to North America




Data source: Semiconductor Industry Association; Forecast: Cahners Economics

## Expansion and contraction in the U.S. semiconductor industry

| | | Expansion | | Contraction | |
|---|---|---|---|---|---|
| | | 1984 | 1988 | 1985 | 1989 |
| Sales | ($ billions) | $11.6 | $13.4 | $8.1 | $14.4 |
| | (% change) | +49% | +31% | -30% | +7% |
| Bookings | ($ billions) | $12.3 | $14.1 | $6.5 | $14.2 |
| | (% change) | +33% | +24% | -47% | +1% |
| Book-to-bill | (ratio/low) | 1.84 | 1.22 | 0.64 | 0.90 |
| ASP* | (% change) | -42% | +18% | -16% | -5% |
| IC leadtimes | (average weeks) | 16.0 | 8.9 | 7.9 | 6.5 |
| Employment | (thousands) | 290 | 266 | 268 | 263 |

* ASP = Worldwide average selling price

Data sources: Semiconductor Industry Association, *Electronics Purchasing*, U.S. Bureau of Labor Statistics; Forecast: Cahners Economics

# U.S. semiconductor sales to continue slow growth

Sales of semiconductors to the United States continued to grow in the first half of 1989, but much more slowly than last year. According to the Semiconductor Industry Association, sales grew 17% in May 1989 from year-ago sales volume. This growth rate is down from a 26% year-ago increase three months earlier and a 32% jump the year before.

If bookings activity is to be believed, expect sales growth to slow even more in the months ahead. Bookings grew just 2.3% above year-ago levels this past May, a far cry from the 23% gains of the previous spring.

Of course, one question is on everyone's mind in this industry: Will there be an industry-wide recession? The answer varies depending on which forecaster speaks. The absence of a consensus among the experts is indicative of the lack of clear signals coming from the economy and the industry.

Compared with the 1985 recession, the current statistics simply don't show the same volatility. Standing back in 1985 at the same point as in the current business cycle, bookings were already plummeting at an annual pace of 39%. This time bookings, although growing only half as fast as a year ago, are still managing to achieve positive growth at an annual rate of 15%.

The lack of a clear positive or negative signal means forecasters are more apt to disagree about 1989 and 1990. Yet most will agree that some kind of turning point will be coming in the months or year ahead. The only questions remaining: How low will the turning point go and when?

Don't be confused by the plethora of semiconductor forecasts. The best business plans depend on at least two forecasts, an optimistic scenario and a pessimistic one. With some realistic and accurate boundaries on your business forecast, chances are you'll succeed.

Where do Cahners Economics' forecasts fall? Right now, we're probably one of the more optimistic, with a mild two-quarter downturn in the latter half of 1989 followed by renewed growth in 1990. The pessimistic scenario: the economy hits a recession, computer orders take a bath and semiconductor prices plunge.

ELIZABETH B. BAATZ

*A column on semiconductors will appear again in the November 27th issue.*